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Research article

Technological change in revitalization – Phytoremediation and the role of nonknowledge

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ABSTRACT

In the 1990s, remediation methods that use plants to investigate and extract contaminations were developed. According to their proponents, these technologies have considerable potential for greening remediation and to develop a more sustainable trajectory for revitalization. Although a great deal of research has been conducted on these technologies they have, so far, rarely been applied in European countries.

This article will contribute a perspective from social science to this debate. By taking an approach inspired by social science practice theories, attention will be drawn to a specific socio-cultural aspect: dealing with nonknowledge. The analysis of remediation practices reveals how the phenomenon of nonknowledge becomes relevant in the process of inventing and applying new technologies. This allows for a better understanding of technological innovation processes in remediation. Based on this understanding strategies are suggested which might increase the use of plant-based technologies in remediation and site management.

1. Introduction

Since the late 1970s, awareness of the negative impacts of contaminants such as chlorinated hydrocarbons, heavy metals, or radionuclides that have accumulated due to human activities led to the establishment of remediation practices in most industrialized countries (cf. Bardos et al., 2011; Brandt, 1993). Remedial practices aim at cleaning up or managing contaminated soil and groundwater in order to prevent, or at least to minimize, negative impacts on human health and environmental functions. In the early years of the new millennium, a shift towards *sustainable remediation* was called for in European countries (Bardos et al., 2011; Dixon et al., 2007; Ellis and Hadley, 2009; Held and Noé, 2012; Thornton et al., 2007). This claim emanated from the awareness of negative environmental impacts of remediation technologies (e.g. energy consumption, CO_2 emissions) but also of their sometimes unfavorable economic (e.g. high clean-up costs) and social impacts (e.g. odors and noise emission impacting neighborhoods). Gentle remediation technologies are understood as being appropriate for *sustainable remediation*. These technologies encompass plant-based approaches and fungal or microbiological methods to deal with soil contamination as well as methods such as monitored natural attenuation to manage groundwater contamination (Cundy et al., 2013). Within this article exemplary plant-based technologies will be considered, summarized under the term *phytoremediation*.

Several advantages of plant-based approaches have been highlighted. The approaches are particular useful for the maintenance of biologically productive soils, the provision of ecosystem services, and the creation of an inherently aesthetic nature of the sites (Cundy et al., 2013). As plants function as solar-driven pumps, such approaches are less energy and resource intensive than classical approaches and support CO_2 sequestration (Cundy et al., 2013; Vangronsveld et al., 2009). Due to limits of plant-based technologies their application has been considered useful for specific sites and uses: large scale sites, sites without feasible alternative uses, and "soft" final uses of contaminated land (Bardos and van Veen, 1996; Cunningham et al., 1997). As a search in Thomson's *Web of Science* revealed, the potential of phytoremediation approaches has been increasingly investigated worldwide since the mid 1990's (cf. Fig. 1). This is also the case in European countries, where the number of scientific publications on phytoremediation has escalated since the late 1990s. However, in European countries, *phytoremediation* is still rarely applied in remediation practice (cf. Cundy et al., 2013; Vangronsveld et al., 2009). It is stated by the proponents of these technologies that they even are not considered

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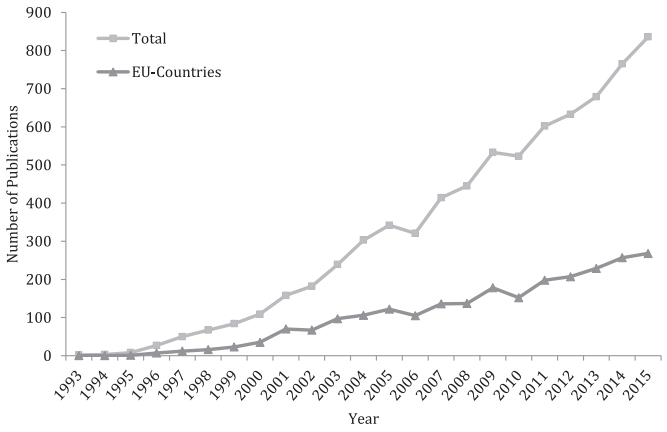

Fig. 1. Publications on phytoremediation listed in Thomson's *Web of Science.*

for application.

Several studies provide explanations for the reluctant uptake of these methods and technologies: a lack of knowledge about details of the methods' functionality, a lack of stakeholders' (e.g. site owners, administrative personnel, consultants) awareness of and experience with new methods, lack of convincing pilot applications, and a focus of remediation industries and legal frameworks on traditional technologies (Cundy et al., 2013; Vangronsveld et al., 2009). Bert et al. (2009) conclude: "Phytoremediation is still an emerging technology that has to prove its sustainability on a field scale" (Bert et al., 2009, 759). The question of how sustainable plant-based technologies are, is part of the technological controversy that builds the context for processes of innovation and invention in the field of remediation. Sustainability of technologies and approaches depends heavily on site specific characteristics. Due to this fact plant-based approaches might require high efforts for site preparation (e.g. importation of soil) or might have even negative effects on a site and its environment (e.g. unintended mobilization of trace elements). Thus, as for other technologies sustainability of plant-based approaches need to be evaluated in each specific context (cf. Held and Noé, 2012).

With this article a perspective from social science will be contributed to the debate. Light will be shed on social processes which lay behind a reluctant uptake of the technologies such as lacking experience and knowledge on methodologies. Attention will be drawn on a specific socio-cultural aspect that is relevant when it comes to inventing and applying new technologies: dealing with nonknowledge. Forms of appearance and social functions of ignorance and nonknowledge recently has been issue of publications in sociology of science (cf. Gross and McGoey, 2015). When using the term nonknowledge throughout this paper it is referred to the term coined by M. Gross (2007) – nonknowledge means knowledge about what is not known. If it can be specified what is not known it is possible to integrate the unknown into strategic action (Gross, 2007).

By approaching the issue of deploying phytoremediation technologies from a socio-cultural perspective, some pointers will be delivered for developing strategies that might enable an increased use of phytoremediation technologies. More precisely, this article follows the hypotheses:

- A praxeological perspective is useful to identify cultural barriers that hinder the introduction of phytoremediation technologies. At this basis strategies can be developed to support the uptake of plant-based approaches in remedial practices.
- It is assumed that the fact that remediation practice continuously has to deal with (unavoidable) nonknowledge impacts the uptake of phytoremediation technologies.

The arguments presented are primarily based on literature about remediation and scientific publications on gentle remediation technologies, as well as on the author's own research within the field of remediation. In order to confirm findings developed from the literature study, guided interviews have been conducted between 2012 and 2014 with 8 experts from the field in Germany, Switzerland, Austria (4 scientists, 3 engineers, 1 employer of a national administrative body), 4 of them were rather critical and 4 rather in favor of the application of plant-based approaches in their countries. Topics of the conversations have been the state of the art of phytoremediation and its application as well as difficulties connected with the technologies mainly in German speaking countries but also in other European countries.

2. Theories of practice - understanding how action and technologies are linked

Within this paragraph, very briefly, the theoretical approach of social practices will be introduced. A praxeological focus on innovation allows understanding the specific interplay of action and artifacts – such as technologies – in daily routines that prevents or facilitates the uptake of new technologies. Throughout further argumentation it will be referred to the terminology introduced here.

Recently, several authors have drawn on practice theoretical approaches in order to study potential paths towards more sustainable societies (e.g. Shove and Spurling, 2013; Shove and Walker, 2010; Spaargaren, 2011). Theories of practices are used in various areas of social science to reconstruct and understand daily routines and ways of using technical or material artifacts (Reckwitz, 2002).[1] These theories approach the understanding of *the social* in a challenging way because they locate *the social* at the interplay of human action and the social order and, thus, in practices (Schatzki, 2002). The definition of what a practice is and of which elements a practice consists differs between authors. A common understanding is that practices are activities carried out regularly by individuals in society. Daily routines, such as bathing, cooking, or heating, but also complex arrangements of performances such as eco-farming, building a house, or repairing a car are understood as practices (Reckwitz, 2002; Schatzki, 2013; Shove et al., 2012). Practices bring together and continuously integrate material components, knowledge, and beliefs through their performance and are organized around a shared practical understanding (Reckwitz, 2002; Schatzki, 2002).

A crucial question is that of persistence and change of practices and authors place different emphasis on stability or change (Hörning, 2004). Practices are seen as both: stable within the continuous integration of the elements of which they consist and changing when the performance is modified by acting and by the uptake of new technologies. As Schatzki (2002) stated, arrangements of practices "are continuously maintained and continually altered by the doings of their components […] The understandings, rules, and teleoaffective structures that organize integrative practices frequently change. So, too, do the doings and sayings that constitute these practices. These two processes can be called 'reorganization' and 'recomposition'." (Schatzki, 2002: 238, 240).

This article draws extensively on the ideas formulated by

[1] So far no unique shape of a practice theory exists. Therefore usually it is referred to practice theories (using plural form) or practice theoretical approaches.